The Implementation of Payload Safety in an Operational Environment

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Abstract. The objective of this paper is to define the safety life-cycle process for a payload beginning with the output of the Payload Safety Review Panel and continuing through the life of the payload on-orbit. It focuses on the processes and products of the operations safety implementation through the increment preparations and real-time operations processes. In addition, the paper addresses the role of the Payload Operations and Integration Center and the interfaces to the International Partner Payload Control Centers.

INTRODUCTION

The Payload Operations Integration Center (POIC), at the Marshall Space Flight Center (MSFC), is chartered by the ISS program to perform payload operations safety responsibilities specifically for NASA payloads and Station-wide in support of all International Partners' (IP) payload safety requirements. Payload Operations Safety functions performed at POIC/MSFC in support of ISS is unique and separate from those safety functions performed at JSC. The value of POIC, as the center of payload operations safety, is that decades of payload experience on many manned space programs, combined with ISS payload-specific and safety training, yields an unparalleled base of knowledge and expertise from which to fulfill the safety functions described in this paper

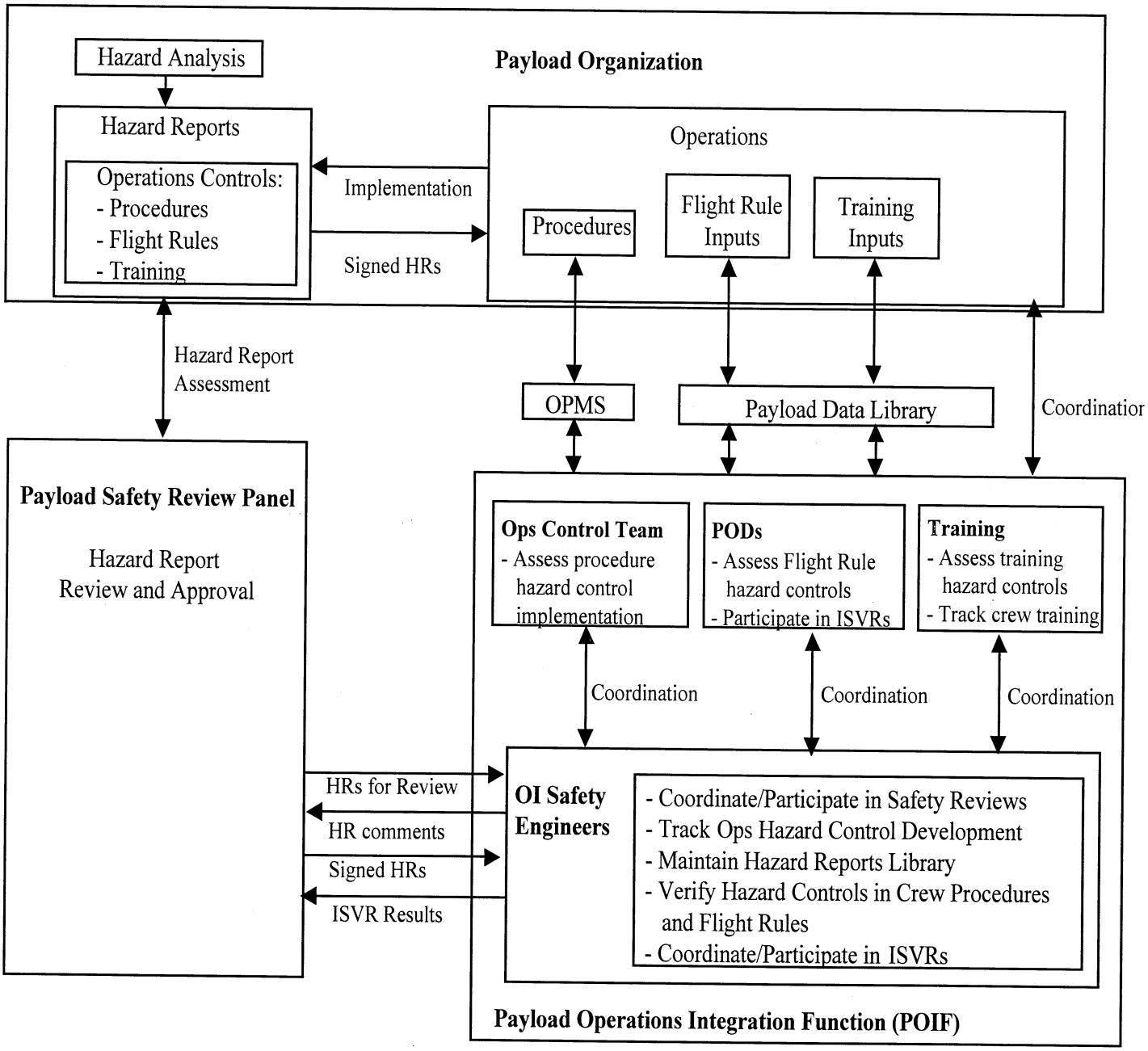
PRE-FLIGHT PAYLOAD OPERATIONS SAFETY

The first step in the operational safety process is the assessment of a Safety Data Package (SDP) by the Johnson Space Center (JSC) Payload Safety Review Panel (PSRP). The SDP goes through a series of phased reviews. The number of reviews depends on several factors including payload complexity. The payload customer defines known or conceived operational hazards in hazard reports included in the SDP. An operational hazard control is defined as a method for preventing or controlling a known potential hazardous situation. During this safety data pack review, POIC Safety reviews the hazard reports, and ensures that all hazard controls identified are safe, effective, and feasible. At the conclusion of each safety review, the hazard reports are signed (by both the payload customer and PSRP chairman) and contain the approved operational hazard controls. These hazard reports are the basis for operational hazard control implementation.

Operational hazard controls fall into one of three categories: Crew Procedures, Flight Rules or Training. The most common implementation of operational hazard controls is through crew procedures. The payload customer, who may be a NASA payload or an IP, develops the procedures and incorporates all procedural hazard controls.

Flight Rule hazard controls are verified in a similar manner to procedural hazard controls. As with procedures, POIC Safety verifies that all Flight Rule hazard controls identified in the hazard reports are properly documented. POIC Safety develops the necessary Flight Rule consistent with the hazard control inputs given by the payload customer and the payload hazard reports, and those are submitted for integration with other POIC developed Flight Rules.

Payload Operational Hazard Control Implementation and Independent Safety Verification Review Process



The responsibility for implementation of training hazard controls resides with the payload customer. Training as a stand-alone control for hazards is allowed only when a technique, skill, or perception needed to control hazards cannot be captured by procedures or flight rules. The payload customer provides to the crew the training identified as the controlling mechanism. POIC Safety monitors the training hazard controls and ensures that the training activities are scheduled.

To document all payload operations hazard controls in a single reference product, POIC Safety produces a Payload Hazard Control Matrix (PHCM). The PHCM is a compilation of all mission specific operational hazard controls, and also tracks the implementation and verification of the hazard controls. This is a control board-approved product for reference in real-time operations. The verification status of crew procedures and flight rules, including procedure references and rule numbers to control hazards, resides in the PHCM. Also, POIC Safety maintains a status of training and course completion dates to track training hazard controls.

In addition to developing the PHCM, POIC Safety builds a Payload Hazard On-orbit Re-verification and Maintenance Log (PHORML), if required, following the safety reviews. Due to the longevity of ISS, it's anticipated some payloads may remain on-orbit for extended periods of time. Payloads may require re-verification or maintenance activities to be performed in order to sustain hazard controls documented in the hazard reports. The PHORML is used to track on-orbit re-verifications or maintenance activities. It consists of information about the hazard control, which states when a reverification item needs to be verified on the ground and/or how often a maintenance item is to be performed on-orbit. The PHORML is only used to track on-orbit execution of the re-verification or maintenance activity, not development of the associated procedure.

Once the PSRP process is completed and the POIC Safety has developed the PHCM and PHORML, there is a final phase of operational hazard control verification. This final process is called the Independent Safety Verification Review (ISVR). The purpose of an ISVR is to provide a final, independent, top-to-bottom assessment that all operations controls defined in the payload hazard reports are correctly reflected in the crew procedures. The ISVR, as a station-wide payload function, is also performed on all International Partner payloads, Lab Support Equipment (LSE) and integrated hazards. The ISVR begins as soon as the signed Phase III hazard reports and baseline crew procedures become available for a particular payload or integrated rack. During these inspections, implementing information, such as the procedure filename and step, is provided to the POIC Safety team for inclusion in the PHCMs. POIC Safety reviews and assesses the procedures and flight rules against the signed Hazard Reports, the Payload Hazard Control Matrix (PHCM) and the payload customer-provided operational hazard control references to ensure all operational controls are properly implemented. POIC Safety identifies any problems with the procedures and works with the payload customer to implement and verify correct controls in the crew procedures. Following all assessments on crew procedures and flight rules, a Certification of Flight Readiness (CoFR) statement is delivered to the Space Station Payloads Program Office endorsing all implementation of products used in real-time operations have been independently verified for safety compliance.

Along with payload hazard reports, there is a report for integrated hazards, known as the Integrated Experiment Hazard Assessment Report (IEHA) generated by the Mission Operations Directorate (MOD) at the Johnson Space Center. For these assessments, integrated hazards are defined as those hazards associated with the interaction of one payload to another, or the interaction of a payload with the ISS systems or Government Furnished Equipment. POIC Safety is a Responsible Verification Organization for mission-based IEHA reports. The purpose of the IEHA is to document how MOD addresses integrated hazards for the payloads on-board the ISS for each stage and/or flight. The IEHA documents MOD organizational accountability for the integrated hazard controls.

The mission-specific IEHAs are distributed in three stages: preliminary, draft, and final. Once the preliminary IEHA is distributed for review, POIC Safety conducts an assessment and provides input from an integrated payload hazard standpoint, identifying potential problem areas and/or new verification requirements. After POIC Safety's preliminary submittal is delivered, an Open Items Log (OIL) will be provided by MOD to POIC Safety for tracking purposes. The OIL is used to track open items on the IEHA, which all open items are continually reviewed by POIC Safety for awareness of any change, until all are items are closed for the final IEHA delivery. During this time POIC Safety remains cognizant of any significant changes, either payload-related or ISS-related anomalies that could create on-board hazards for the ISS or payloads. Upon completion of the IEHA draft, POIC Safety submits a signed letter of concurrence stating all verification information has been reviewed and the verification requirements have been satisfied. A final edition of the IEHA is produced from the draft submittal, and delivered to POIC and posted onto the PSRP website.

Another pre-flight duty of POIC Safety is to familiarize the crew and ground support personnel on all payload operational hazard controls. During the crew's Payload Complement Training, POIC Safety presents the controls for the mission-specific payload hazards, including operational hazard controls, what the controls are, and the fire detection method (front breather payload vs. rear breather payload). A payload is considered a "front breather" if it exchanges air with the cabin for cooling purposes, however a payload is considered a "rear-breather " if it exchanges air within the rack, utilizing the fans installed within a rack facility for cooling.

POIC Safety trains and educates the POIC real-time flight controllers on all mission- specific payload operational hazards and controls. POIC Safety produces a detailed package of all the information about the hazards and hazard controls, listing the hazard report number, verification methods, any applicable flight rules, and a diagram or picture of the payload or rack pointing to the control mechanism. This training is a required class for flight controller certification for real-time operations. There is further training given to specific flight controllers on NSTS 18798-B "Interpretation Letters" document, the requirements of Hazard Reports, and the understanding of payload toxicity levels and components, payload fire detection and suppression, and payload maintenance items.

A final safety task prior to real-time operations is the verification of the ISS Hazardous Material (HAZMAT) Database for payloads. HAZMAT is information about the chemical and biological materials flown in the STS and ISS pressurized volumes at any given time. HAZMAT contains: Payload hardware containing toxic samples, Toxicity Hazard Levels, IMS (bar code) location identifier, Toxic Sample Name, Toxic sample chemical/biological properties, concentration and volume. The HAZMAT tables are submitted to POIC Safety by approximately L-1 month for review and processing from the Toxicology Office at JSC. POIC Safety verification includes, validating proper payload nomenclature and assuring the data is correct according to signed hazard reports. After such review, POIC Safety submits comments to the toxicology office and notes any discrepancies and/or approvals. Once the final version is given to POIC Safety from the toxicology office, it is distributed to appropriate POIC flight controllers for console operations.

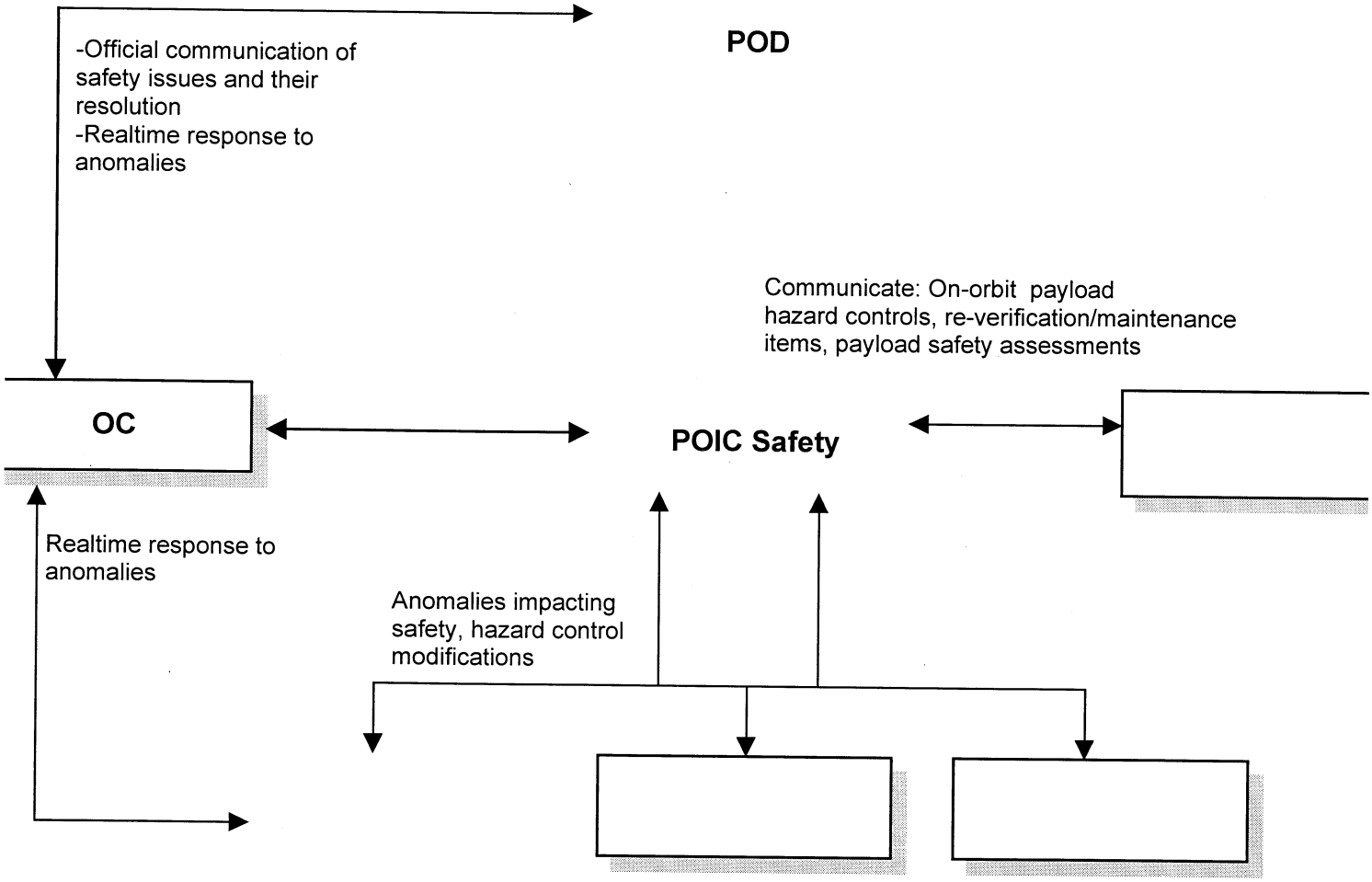
POIC Safety integrates all real-time products and necessary support information into a mission specific booklet, titled " Safety Product Book". The Payload Operations Director (POD) and Operations Controller (OC) both receive a Safety Product Book and a CD-ROM with all mission specific support material.

REAL-TIME PAYLOAD OPERATIONS SAFETY

There are several facets of safety during real-time operations. Overall real-time payload safety is the responsibility of the POIC cadre under the direction of the POD. The POIC flight control team works with both the Mission Control Center-Houston team and the ISS MER Safety team on any payload safety problems, responses, and impacts. In addition, the POIC flight control team is responsible for making sure all payload activities conducted, either by the crew or remotely from the ground, adhere to documented Flight Rules and other safety constraints.

Within the POIC flight control team there is a designated position, the Operations Controller (OC), to monitor and maintain cognizance of hazard controls and potential safety situations on-board. The OC is specifically trained to be the payload operations response in an off-nominal situation involving SOF. The POD is the official interface to MCC-H and MER, and OC is the safety voice. POIC Safety personnel are the safety experts, and are called in as necessary, to support critical safety issues or questions. Throughout a mission, POIC Safety works closely with the OC and POD to ensure awareness about payloads that have operational hazards. For payload safety issues requiring safety assistance, the OC can request for POIC Safety to be called in with POD approval. POIC Safety uses resources such as, Safety Data Packs, signed Hazard Reports and the PHCMs to help with payload anomaly resolutions. Along with the signed hazard reports, the PHCM serves as a definite resource for ops hazard controls and can be accessed through the real-time websites. In the case of a safety payload anomaly, POIC Safety would notify and coordinate payload safety issues/dispositions with ISS Mission Evaluation Room (MER) Safety to ensure proper safety representation was coordinated for a payload Safety of Flight (SOF) issue.

POIC Safety Interfaces


POD
-Official communication of safety issues and their resolution
-Realtime response to anomalies
Communicate: On-orbit payload hazard controls, re-verification/maintenance items, payload safety assessments
OC
POIC Safety
Realtime response to anomalies
Anomalies impacting safety, hazard control modifications

POIC Safety reviews all Operations Change Request (OCR) for adherence to payload safety and to verify that hazard controls remain in effect. When crew procedures are released for review, via OCR, POIC Safety reviews crew procedures for any changes to an existing operational hazard control, implementation of a new hazard control, or change in the step number where the hazard control was to be found. If a change were made to an existing hazard control or implementation of a new hazard control, the PSRP would be notified through the Payload Safety Engineer (PSE) at JSC, and a meeting with the PSRP, PSE and POIC Safety would be coordinated. Once the PSRP approved/disapproved the ops hazard control change, POIC Safety communicates the message to POD, and documents the results in the OCR. After receiving approval from the Flight Director through POD, the POIC takes action to implement such resolution.

During real-time operations, POIC Safety is responsible for keeping all safety products in the utmost condition with current information. Because of the changes that can occur within crew procedures, the PHCM often requires modifications. When it is appropriate for an update to occur, POIC Safety retrieves the master POHD and makes the changes. Once all changes are incorporated correctly in the PHCM, an OCR must be developed and submitted for cadre review and concurrence. This allows the process to implement the changes to the baseline product. After concurrence has been given, the new version of the PHCM is posted onto the realtime web sites and other proper locations. POIC Safety delivers a hardcopy to the POD and OC at that time, for revision of their Safety Product Book.

Another real-time product that could require updating , is the Integrated Safety Product Matrices (ISPM) s. The ISPM includes payload information such as fire detection and suppression and toxicity levels involved with payloads. The OC and POD use the ISPM as a reference sheet during real-time operations. If an OCR effects the information in the ISPM, POIC Safety utilizes internal work instructions to update the product used by the real-time cadre. After dispositioning the OCR, POIC Safety retrieves the master ISPM lists and makes appropriate updates. Once the ISPMs have been updated with current data, POIC Safety delivers hardcopies and an updated CD ROM to the OC and POD console, and collects the old versions to prevent confusion. The turnaround time for these updates are immediate, for it is important for the POIC to always have a current and accurate reference of information, to guarantee safe payload operations onboard ISS.

CONCLUSION

This document was to convey the implementation of payload safety in an operational environment. It defines the process and responsibilities by which operational hazard controls are identified, implemented, and verified for all US partner payloads and Stationwide partner payloads on the ISS. POIC Safety continues to support and lead various efforts for pre-flight activities, as well as real-time operations, to ensure the safety of all payload operations onboard the ISS.

REFERENCES

NASA/MSFC, *Payload Operations Handbook,* SSP 52000-PDS Rev. B, February 1999a.
NASA/MSFC, *Implementation Plan for Operational Control of US Partner Payload Hazards* SSP 58300, November 1998.
POIC Safety Handbook